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A DESCRIPTION AND ANALYSIS OF LONGITUDINAL RECORDS OF DEVELOPMENT OF ELEMENTARY SCHOOL CHILDREN IN FERNDALE, MICHIGAN.

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THE GOAL OF THIS STUDY WAS TO INCREASE THE UNDERSTANDING OF PROFESSIONAL AND LAY PEOPLE REGARDING CHILDREN'S PATTERNS OF DEVELOPMENT, PARTICULARLY IN REGARD TO EDUCATIONAL PROBLEMS. THE SPECIFIC PARTS OF THE STUDY RELATED TO THIS PURPOSE WERE--(1) THE ANALYSIS OF RELATIONSHIPS BETWEEN PHYSICAL, MENTAL, AND READING GROWTH, (2) THE COMPARISON OF DIFFERENCES BETWEEN SIBLINGS AND UNRELATED CHILDREN, AND (3) A COMPARISON OF THE FERNDALE DATA AND DATA COLLECTED AT THE UNIVERSITY SCHOOL IN ANN ARBOR. THE MAJOR PORTION OF THE DATA WAS DRAWN FROM RECORDS OF THE SCHOOL DISTRICT OF THE CITY OF FERNDALE, MICHIGAN. SIX YEARS AGO, THIS SCHOOL DISTRICT BEGAN A LONGITUDINAL TESTING PROGRAM OF CHILDREN IN KINDERGARTEN THROUGH EIGHTH GRADE WHO WERE MEASURED TWICE YEARLY FOR PHYSICAL, MENTAL, AND ACADEMIC GROWTH WITH ALL MEASUREMENTS CONVERTED INTO AGE UNITS. RECORDS WERE AVAILABLE ON 2,920 CHILDREN IN THE ELEMENTARY GRADES. IN ADDITION TO TESTING THEORETICAL CONCEPTS OF DEVELOPMENT, STATISTICAL ANALYSES OF THE DATA PERMITTED CONTRASTS OF PATTERNS OF DEVELOPMENT RELATED TO SUCH FACTORS AS SEX, RACE, SOCIOECONOMIC STATUS, CLASS SIZE, AND INSTRUCTIONAL GROUPING. THE FINDINGS OF THE FERNDALE PROJECT SUGGEST THAT THE MOST IMPORTANT RESPONSIBILITY OF PARENTS AND TEACHERS IS THAT OF LEARNING HOW TO BETTER COPE WITH THE LARGE AND DYNAMIC VARIABILITY IN GROWTH STATUS, GROWTH RATE, AND GROWTH PATTERN WHICH IS CHARACTERISTIC OF GROWING CHILDREN. (GC)

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by

Warren A. Ketcham, Project Director, and

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* The study was made possible by a grant to the University of Michigan from the United States Department of Health, Education, and Welfare, under the provisions of Public Law 531, 2d Session, 83d Congress. The cooperation of the Ferndale Board of Education and staff was indispensable in carrying out the study.

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INTRODUCTION

Growth and development studies of children in laboratory schools have made an impressive contribution toward shaping current school practices. The general acceptance of research findings by teachers as a basis for classroom practices has, nevertheless, been slow. There are at least two main reasons: (1) Teachers are often skeptical about the extension of principles derived from studies of laboratory school children to children in more typical community schools. (2) When planning changes in instructional programs, many school systems continue to give primary consideration to expediency and tradition.

The present study is based on growth data on children in a typical school community. Consequently, the findings may serve to promote a wider acceptance and use of principles and generalizations which have been derived from studies in laboratory schools and child study centers.

The Ferndale School Community

The School District of the City of Ferndale is located in Oakland County on the northern border of Detroit, Michigan. In Michigan the boundaries of school districts were established before the boundaries of cities. As a result, the School District serves all or a part of several cities, as follows: most of Ferndale, all of Pleasant Ridge, and small parts of Royal Oak, Oak Park, and Royal Oak Township.

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The area is predominately residential. Socio-economic levels range from lower to upper. The population of the School District is approximately 50,000.

There are ten elementary schools and a four-year high school in the School District. The enrollment for the ten elementary schools was 4,802 for 1951-52. Elementary classroom teachers numbered 156. The number of elementary pupils per teacher was 29.8.

The School District provides special education for the mentally retarded, visually handicapped, deaf, hard of hearing, speech handicapped, and orthopedically handicapped. In addition to the regular administrative staff, there are three visiting teachers, a homebound teacher, a director of recreation, a psychologist, and a curriculum consultant.

Valuation per school membership child in Ferndale Schools was $8,867 in 1951-52. Per capita cost for educating a child was $234.26. When compared with twenty-five selected schools in Oakland County for 1951-52, the School District ranked tenth in valuation per school membership child and per capita cost.

Background of the Ferndale Testing Program

The periodic testing of pupils' mental abilities and academic achievement became common practice in many school districts in the United States during the past quarter century. The School District of the City of Ferndale was no exception. By 1944 the School District had developed a well organized district-wide testing program. Test results were reported to teachers annually by the Director of Group Testing. The reports to teachers emphasized the importance of having class group averages compare favorably with test norms. The dominant use of test results was to stimulate teachers to seek corrective instructional

procedures which would maintain normative achievement and reduce the number of slow learners. As might be expected in a growing school district, the number of children showing achievement below group averages and test norms multiplied with each increase in enrollment. The result: larger numbers of retentions and an increase in teacher requests for adjustment rooms. The idea that the problem was traceable to some extent to the nature of children and therefore only partially amenable to corrective teaching procedures had not yet appeared.

In a testing report dated April, 1947, it was suggested that some children who were retained did not benefit by non-promotion and that decisions on promotion should be made on the basis of an individual analysis. By 1951 the School District appeared ready to incorporate changes in its testing program designed to emphasize the extent of individual differences in the capacity of children to profit from instruction and to make it more possible for teachers and administrators to assess the individual needs of pupils as a basis for improving teaching methods and the curriculum.

The Revised Ferndale Testing Program

In October, 1951, the Administrative Council adopted and the Board of Education approved revision of the testing program. The main reason for a new testing program was explained by the following statement:

> "The testing program for 1951-52 represents an attempt to further assist parents and teachers in helping individual children to learn more and better as they grow and develop. At the same time it recognises that today we know many things about children which we did not know twenty-five years ago. For example, we are much more willing now to recognise that children of a given age or grade placement are very different in many ways. They are different in height, weight, and strength. One of the most noticeable of these differences is the speed with which they learn. Studies of many children have shown that their rates of learning are closely related to an individual total-growth pattern"(13, p.19).

The revised testing program was established first on a trial basis for grades kindergarten, one, and two. In March, 1952, the Administrative Council adopted the following program for grades kindergarten through eight: (14)

Kindergarten:

October: Height, Weight, Grip, Dentition

April: Height, Weight, Grip, Dentition

First Grade:

October: Height, Weight, Grip, Dentition

April: Height, Weight, Grip, Dentition
Otis Quick-Scoring Test of Mental Ability
Gates Primary Paragraph Reading Test

Second Grade:

October: Height, Weight, Grip, Dentition
Gates Primary Paragraph Reading Test

April: Height, Weight, Grip, Dentition
Gates Advanced Primary Paragraph Reading Test
Otis Quick-Scoring Test of Mental Ability

Third Grade:

October: Height, Weight, Grip, Dentition (starting in 1952)
Durrell-Sullivan Reading Achievement Capacity Test

April: Height, Weight, Grip, Dentition
Otis Quick-Scoring Test of Mental Ability (starting in 1952)
Gates Advanced Primary Paragraph Reading Test (starting in 1953)

Fourth Grade:

October: Height, Weight, Grip, Dentition (starting in 1953)
Iowa Every-Pupil Test of Basic Skills
Reading - Elementary Form
Arithmetic - Elementary Form

April: Height, Weight, Grip, Dentition

Fifth Grade:

October: Height, Weight, Grip, Dentition (starting in 1954)
California Test of Mental Maturity, Elementary '50
S-Form

April: Height, Weight, Grip, Dentition (starting in 1955)

Sixth Grade:

October: Height, Weight, Grip, Dentition (starting in 1955)
Iowa Every-Pupil Test of Basic Skills
Reading - Advanced Battery
Arithmetic - Advanced Battery
Work Study - Advanced Battery

April: Height, Weight, Grip, Dentition (starting in 1956)

Seventh Grade:

October: Height, Weight, Grip, Dentition (starting in 1956)
California Test of Mental Maturity, Elementary '50
S-Form

April: Height, Weight, Grip, Dentition (starting in 1957)

Eighth Grade:

October: Height, Weight, Grip, Dentition (starting in 1957)
Iowa Every-Pupil Test of Basic Skills
Reading - Advanced Battery
Arithmetic - Advanced Battery
Work Study - Advanced Battery

April: Height, Weight, Grip, Dentition (starting in 1958)

Two characteristics of the Ferndale testing program are closely related to the quantity and quality of the data. First, the testing program was scheduled to begin with grades kindergarten, one, and two in 1952. Grade levels were added only as those grades progressed. Consequently, the number of upper grade children available for inclusion in the present study was very small. Second, the program was planned as a service and in-service project. The tests were administered by classroom teachers with the help of principals, the director of group testing, and the school psychologist. It must be recognized that these circumstances

have imposed some serious limitations on the accuracy and consistency of the data. In the present report every effort has been made to recognize the limitations of the data. Unfortunate and undesirable as they are, it is virtually impossible to secure longitudinal records on all the available children in a typical school system without the support and aid of a large number of staff members, many of whom may consider testing as a minor duty.

Theoretical Basis for the Revised Ferndale Testing Program

The revised Ferndale testing program of 1951 was based on measures used by Olson and Hughes at the child development laboratory of the University Elementary School at the University of Michigan (8). The specific measures used in Ferndale were height in inches, weight in pounds, number of erupted permanent teeth, strength of wrist grip in kilograms, mental development, and reading skill. A measure of carpal ossification, which was advocated by Olson and Hughes, was omitted from the Ferndale testing program. Physical measurements were translated into age units by using Tables for the Translation of Physical Measurements into Age Units (7). Mental age and reading age were secured by translating test scores into age units by means of tables which accompany the particular tests employed. The result was a group of six growth ages: height age (HA), weight age (WA), dental age (DA), grip age (GA), mental age (MA), and reading age (RA). The six growth ages were used (1) to indicate the progress of individual and groups of children toward maturity by comparisons with chronological age and (2) to describe differences within and between children. Olson and Hughes (6) have suggested seven "concepts of growth" important to teachers in their efforts to assess and understand the growth and achievement of children: (1)

Children Differ in Rate and Level of Growth, (2) Growth Has Some Unity When Viewed as a Whole, (3) Children Differ in the Pattern of Growth, (4) Growth with Time Is a Highly Individual Matter, (5) Membership in a Given Family Is Influential in Determining the Pattern of Growth, (6) Growth Has Stability and Continuity and Makes Its Demands for Nurture, and (7) Children Viewed as Wholes Are More Alike than Children Viewed as Parts. The above growth concepts have been derived from repeated measures of the same individuals which resulted in longitudinal records. Although Olson has recognized the preference of other investigators for correlations in cross-sectional studies of groups, he has emphasized the use of evidence from longitudinal records of individual children to support the general hypothesis that "when the data on the growth of children are examined from the point of view of the child as a whole, an underlying unity is discovered in structure, functions, and achievement"(4,p.187).

Hypotheses

The purpose of the present study was to determine whether growth data on a large group of children in a typical school community would lend support to the previously mentioned concepts of growth and the general hypothesis. The following six hypotheses were selected as a basis for analyzing the Ferndale growth data:

1. The physical, mental, and academic development of growing children are positively related.

2. When the same children are measured repeatedly as they grow older and pass through school, the variability among them increases, irrespective of instructional practices.

3. Some children show systematic changes in their learning patterns so that some children who start late ultimately achieve a high status.

4. There are substantial similarities in the test records of children of the same family.

5. In predicting the ultimate achievement of children, differences in the physical and mental development of children upon entrance to school are as important as school practices.

6. When the expectancies of parents and teachers for children are established through the use of longitudinal test records, it is found that a large majority of children show positive gains which bear a close relationship to their developmental potential.

Number of Children Tested

In February, 1952, there were 730 children enrolled in kindergarten, 579 in Grade 1, 591 in Grade 2, 644 in Grade 3, 549 in Grade 4, 507 in Grade 5, and 447 in Grade 6. These enrollments provided the possibility for securing 4,047 records of one to six years' duration. The number of records available for analysis was substantially reduced by transfers to non-public schools, by children moving away from the School District, and by the presence of incomplete and invalid records. Growth records of children who had attended kindergarten only were not utilized because of their brevity. After careful examination a total of 2,920 records were chosen for analysis.

The present study was concerned primarily with the longitudinal records. The following minimum criteria were established for including individual records in the longitudinal group: 10 height ages, 10 weight ages, 10 dental ages, 10 grip ages, 3 reading ages, 3 mental ages, and 10 organismic ages. 1,373 records met this criteria.

There were 1,547 shorter records which did not meet the criteria for inclusion in the longitudinal group. These records plus those in the longitudinal group served as the basis for a cross-sectional analysis.

RESULTS OF THE TESTING PROGRAM

The Longitudinal Records

A longitudinal growth record is derived from repeated measurements of the same child through time for a given characteristic, i.e., height. Longitudinal records are particularly effective in identifying idiosyncrasies in the growth of a single child or in illustrating differences between growing children.

As will be shown later, longitudinal records lend themselves to graphic illustration for the purpose of gaining an approximation of individual differences in the growth of children. For purposes of statistical analysis, however, a more precise method was necessary. For the present study this need was provided by the correlation of each growth age distribution with chronological age for every child. The IBM Type 650 Magnetic Drum Data Processing Machine was used. This operation provided a coefficient of correlation between chronological age and growth age, the slope of a regression line, and the y-intercept of the regression line for each longitudinal growth age record for every child.

Linear and Non-Linear Records

Inspection of the coefficients of correlation between the growth age distributions and the chronological age distributions for different growth ages revealed large differences, both within a given growth age and between the various growth ages. On the basis of the size of the correlation coefficients, the longitudinal records were divided into a linear group and a non-linear group. Records for which the coefficient of correlation was +.90 or better were arbitrarily and operationally defined as linear. Conversely, records for which the correlation

coefficient between growth ages and chronological ages was +.89 or less were called non-linear. Table 1 shows the number and percentage of linear growth records for each growth age.

TABLE 1

Number and Percentage of Children Exhibiting Linear Growth Based on a Correlation Coefficient of +.90 or Better between Growth Age and Chronological Age

Growth Age	Number of Records	Number of Linear Records	Percentage of Linear Records
Height Age	1,356	1,333	98.30%
Weight Age	1,358	1,290	94.99%
Dental Age	1,348	1,031	76.48%
Grip Age	1,360	310	22.79%
Reading Age	1,173	616	52.51%
Mental Age	1,133	813	71.76%
Organismic Age	1,359	1,172	86.24%

The differences in percentage of linearity between growth ages presented in Table 1 can be attributed to several factors. Height age and weight age show the greatest linearity because they are affected by environmental factors to a lesser degree than the other growth ages. Also, they were measured with more valid and reliable instruments. Dental growth is as independent of environmental conditions as height and weight,

but teachers and nurses were not as skillful at counting teeth as they were at measuring height and weight. Because of the low reliability of the measurements made with the hand dynamometer, the lowest percentage of linear records was secured for grip age. The percentage of linear records for mental age is less than the percentage for height age, weight age, and dental age, but greater than that for grip age and reading age. Undoubtedly, some of the lack of linearity among the mental age records can be attributed to poor test reliability. However, the relatively high percentage of linear mental age records may very well be accounted for by the theoretical assumption that mental growth is to some extent like height, weight, and dental growth in that it is highly influenced by maturational factors. The low percentage of linear records for reading age is in all probability due to questionable test validity and reliability and the susceptibility of reading growth to differences in environmental conditions which influence children's attitudes toward reading and their opportunities to learn to read. Organismic age is the mean of the other ages. Consequently, the number of linear organismic age records is large.

Inspection of the non-linear records have revealed the presence of two types: (1) erratic records which could very well have been the result of testing and recording errors and (2) records which appeared to be curvilinear. The first type was not used for purposes of statistical analysis of the longitudinal records. The purpose of the elimination was to avoid, insofar as possible, testing and recording errors and to gain reasonable assurance that the longitudinal record could be used to represent the actual growth which occurred. The curvilinear-type records will be discussed in a later section.

Data from the linear longitudinal records will now be presented.

Interrelationships in Physical, Mental, and Academic Growth

During recent years a number of studies have been reported concerning the relationships between various indices of physical, mental, and educational growth. Tuddenham and Snyder (12) employed the coefficient of linear correlation as a measure of the relationship between height, weight, and strength. The coefficients of correlation resulting from their study showed a range of +.25 to +.78 between height and the other measures, a range of +.18 to +.78 between weight and the other measures, and a range of +.18 to +.73 between strength and the other measures. They concluded that there were certain regularities running through their data and that strength was the most nearly independent measurement which they obtained. Paterson (9) and Jones (1) studied the relationships between physical size and mental status. From their findings they concluded that these relationships are too low to be of predictive value. In a recent study Nally (3) reported a positive relationship of predictive dimensions between height and the beginning of growth in reading.

Because the conclusions reached by the various studies are seemingly inconclusive and in view of the fact that many studies have employed status as the basic index of growth, it was felt that a fruitful approach to the Ferndale data might be an analysis of the relationship between the rates of development of the different growth ages which resulted from the testing program. For this purpose a sample of one hundred subjects was randomly drawn from those children whose individual distributions of height age, weight age, dental age, grip age, reading age, mental age, and organismic age were linear. The raw data were the slopes of the

regression lines of the various growth age distributions. . . .

Table 2 presents the coefficients of correlation between the twenty-one possible pairs of growth age rates for the sample of children. With ninety-eight degrees of freedom the coefficients of correlation between the rates of HA and WA, HA and OA, WA and OA, CA and MA, GA and DA, RA and MA, RA and OA, and MA and OA are significant at the .01 level. With the same number of degrees of freedom, the coefficients of correlation between WA and MA are significant at the .05 level. The correlation coefficients between HA and DA, HA and GA, HA and RA, WA and DA, WA and RA, DA and GA, DA and RA, DA and MA, DA and OA, and GA and RA are not statistically significant.

TABLE 2

Coefficients of Correlation between Rates of the Seven Growth Ages

	HA	WA	DA	GA	RA	MA	OA
HA		**.3411	.0554	.1228	*.1971	*.2525	**.3841
WA			-.1942	**.2550	.1616	*.2105	**.4107
DA				-.0427	-.1146	.0977	.0790
GA					.1395	**.2622	**.4026
RA						**.5066	**.6286
MA							**.7847

**Significant at .01 level
*Significant at .05 level

Patterns of Growth

At any given age children differ in their level of growth. A child whose growth age is greater than his chronological age is said to be growing at a high level. Conversely, a child whose growth age is lower than his chronological age is said to be growing at a low level. The y-intercept of the regression line of each longitudinal growth age record has provided an index of the level of growth at a hypothetical starting point for that record. The slope of the regression line of each growth age record has provided a rate for that record. The combination of growth level at a hypothetical starting point and growth rate for a given longitudinal record provides the basis for identifying distinct types of growth patterns. The four possibilities for growth patterns are illustrated by the following equations:

(A) + y-intercept + slope $>$ 1.0 = early and rapid growth

(B) + y-intercept + slope $<$ 1.0 = early and slow growth

(C) - y-intercept + slope $>$ 1.0 = late and rapid growth

(D) - y-intercept + slope $<$ 1.0 = late and slow growth

Figure 1 presents the possibilities for growth patterns based on the four equations. Figures 2 and 3 show the actual line graph of the longitudinal records of two hundred pupils for mental age and for reading age. The two hundred pupils are a representative sample from the available longitudinal linear and non-linear records (1,173 for reading age and 1,133 for mental age). The similarity between Figure 1 and Figures 2 and 3 suggests that a large percentage of growth patterns fit the hypothetical patterns given by the four equations. Table 3 presents the number and percentage of the linear growth age records which are comparable to the hypothetical growth patterns. That is, the percentages in the table show

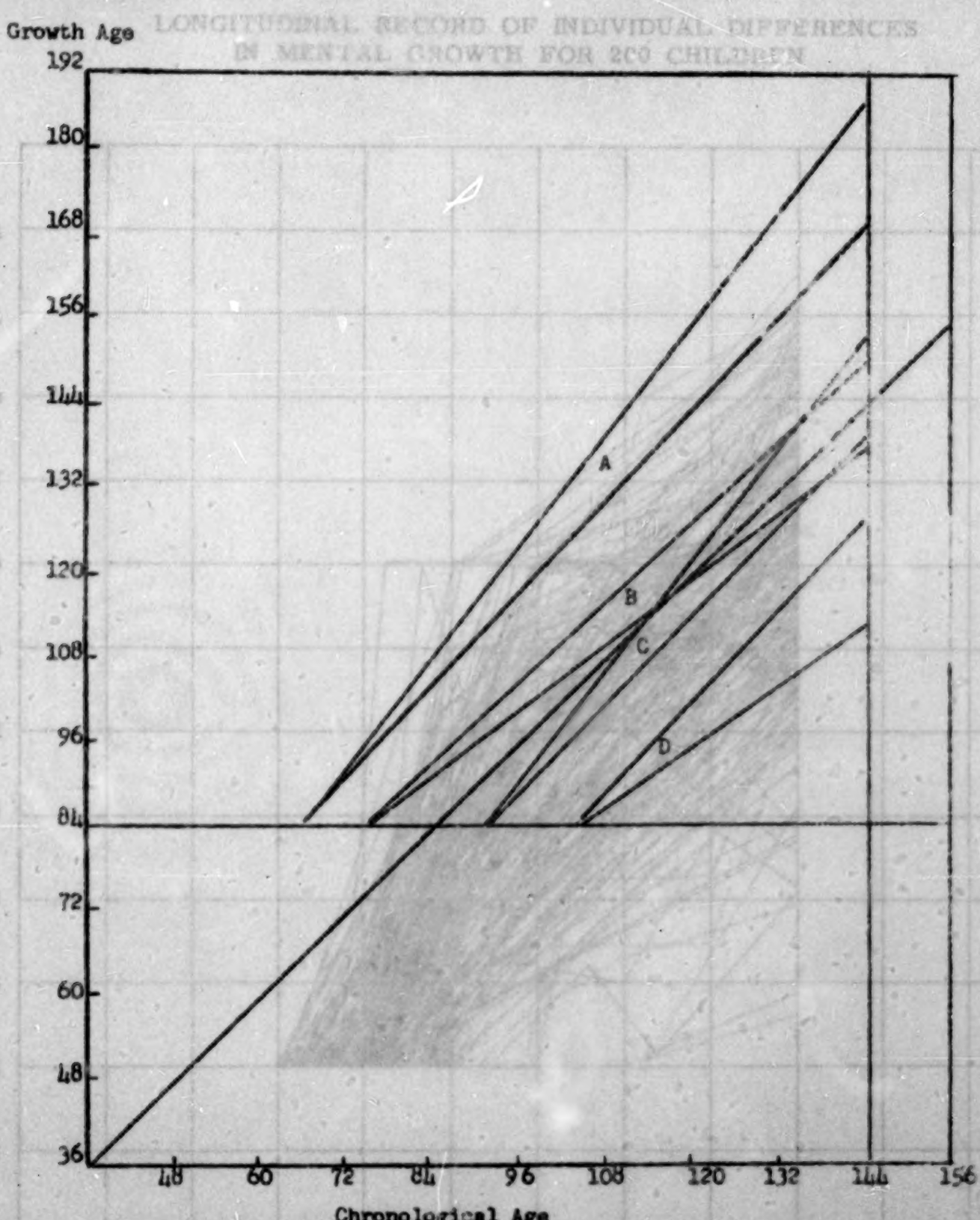

Fig. 1. Model of types of growth patterns:
A (+ Y-intercept + Slope > 1.00), B (+ Y-intercept + Slope < 1.00).
C (- Y-intercept + Slope > 1.00), D (- Y-intercept + Slope < 1.00).

LONGITUDINAL RECORD OF INDIVIDUAL DIFFERENCES
IN MENTAL GROWTH FOR 200 CHILDREN

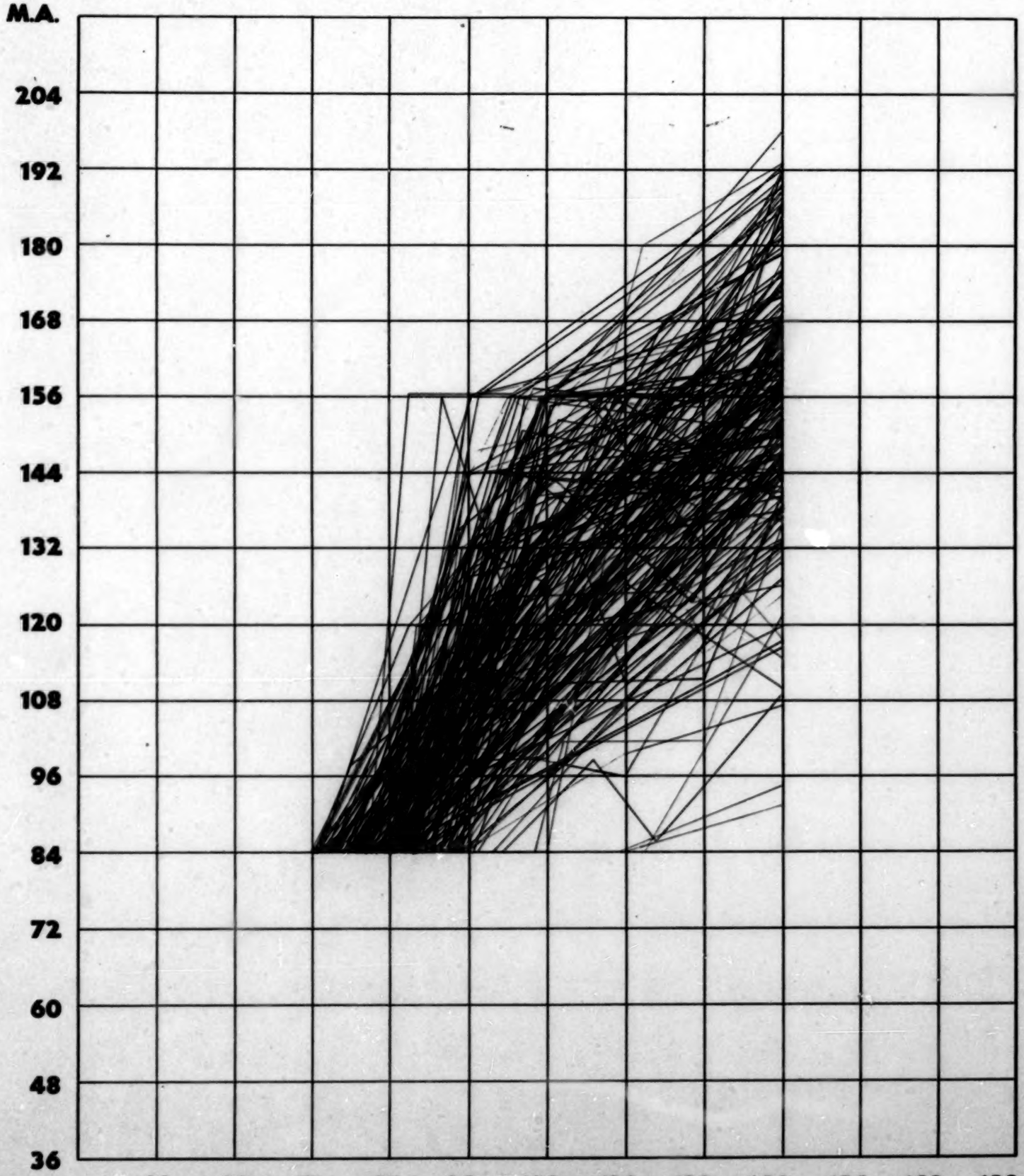

Figure 2.

LONGITUDINAL RECORD OF INDIVIDUAL DIFFERENCES
IN READING GROWTH FOR 200 CHILDREN

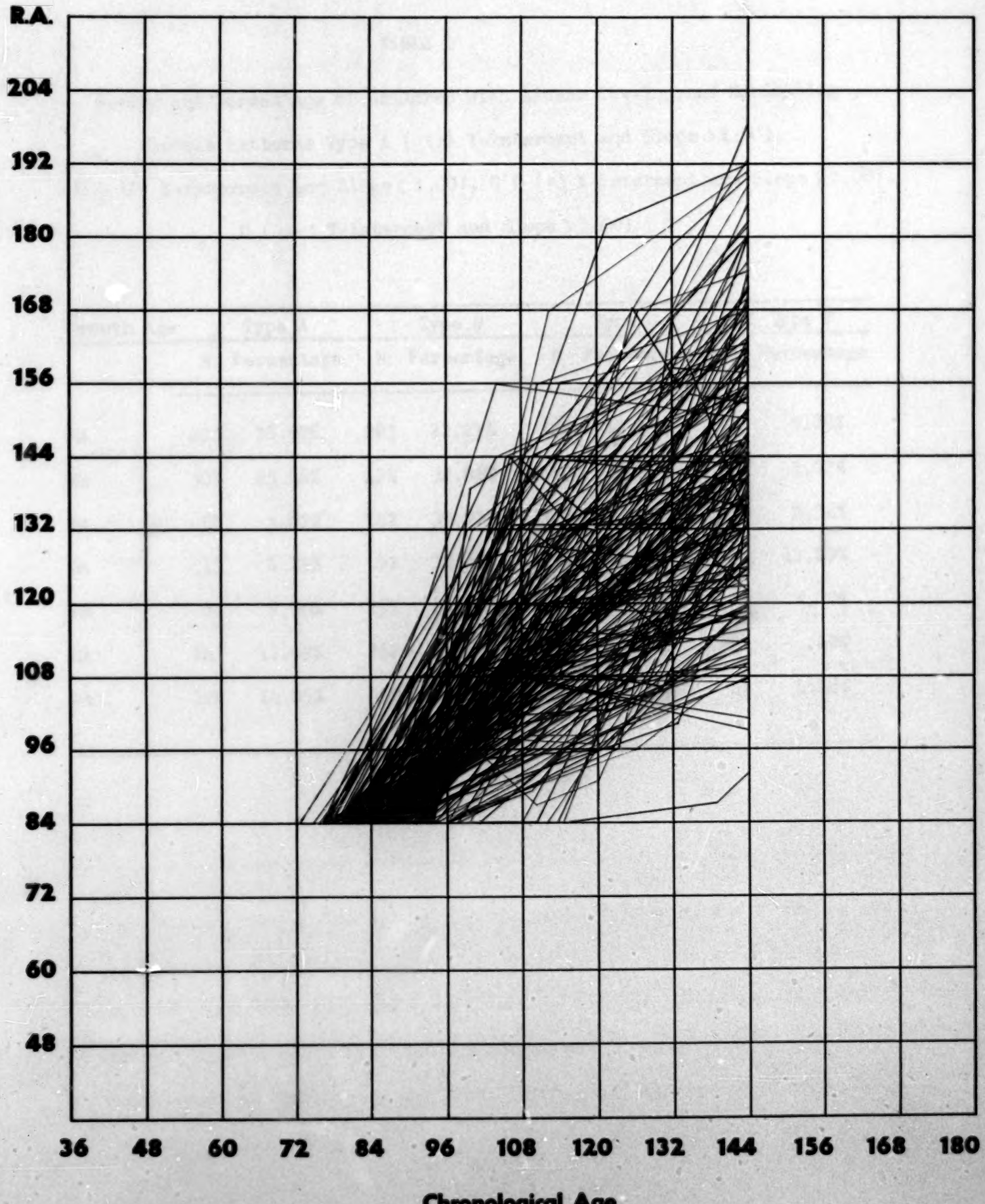

Figure 3.

TABLE 3

Number and Percentage of Children with Linear Development Exhibiting Growth Patterns Type A ((+) Y-intercept and Slope > 1.00), B ((+) Y-intercept and Slope < 1.00), C ((-) Y-intercept and Slope > 1.00), D ((-) Y-intercept and Slope > 1.00)

Growth Age	Type A		Type B		Type C		Type D	
	N	Percentage	N	Percentage	N	Percentage	N	Percentage
HA	253	18.97%	283	21.23%	719	53.93%	78	5.85%
WA	303	23.48%	424	32.86%	515	39.92%	48	3.72%
DA	52	3.82%	542	39.91%	378	27.83%	59	4.34%
GA	13	4.19%	61	19.67%	201	64.83%	35	11.29%
RA	61	9.90%	255	41.40%	289	46.92%	11	1.79%
MA	143	17.59%	262	32.23%	404	49.62%	4	.49%
OA	174	14.85%	406	34.64%	543	46.33%	49	4.18%

that when lines of best fit were established for a large group of pupils in the Ferndale school system, the lines crossed a line drawn parallel to the x-axis at approximately the points indicated in Figure 1 and in the percentages of the total group given in Table 3.

Table 4 shows the number of children whose growth patterns for several growth ages followed the same pattern.

Table 4

Number of Records Exhibiting a Common Type of Linear Growth Pattern for Three or More Growth Characteristics

Number of Characteristics	Types of Growth Pattern			
	A	B	C	D
Three	--	12	55	--
Four	--	10	58	--
Five	--	--	16	--
Six	--	--	5	--

The data in Table 4 indicate a general lack of concordance of growth age patterns for all excepting Type C. However, Table 5 shows that when organismic ages were computed from the six available growth ages and the results were compared with reading age pattern, 45 per cent of the linear records show a common pattern for reading age and organismic age.

Table 5

Number and Percentage of Linear Records Exhibiting a Common Pattern for Reading Age and Organismic Age (N=616)

	A	B	C	D
Number	16	102	154	3
Percentage	2.59%	16.55%	25.00%	.48%

Furthermore, the relationship holds for Type C for a larger percentage of the children than for any other type.

The problems experienced by teachers in dealing with children who exhibit late and rapid growth patterns cannot be overemphasized. The nature of the problems can be more fully appreciated by a careful examination of Figure 4, which illustrates the case of a child whose growth pattern followed Type C. At 78 months of chronological age, all of the child's growth measurements but one were below her chronological age. By 138 months of chronological age, all of her growth measurements were above her chronological age. The child's I.Q. was 100 when she was 78 months old and 137 when she was 138 months old. Her reading age did not equal her chronological age until after she was eight years old. By age twelve she had a reading age of fifteen years. Children exhibiting Type C growth patterns have been previously identified at the University School in Ann Arbor. An illustration is provided in Figure 5.

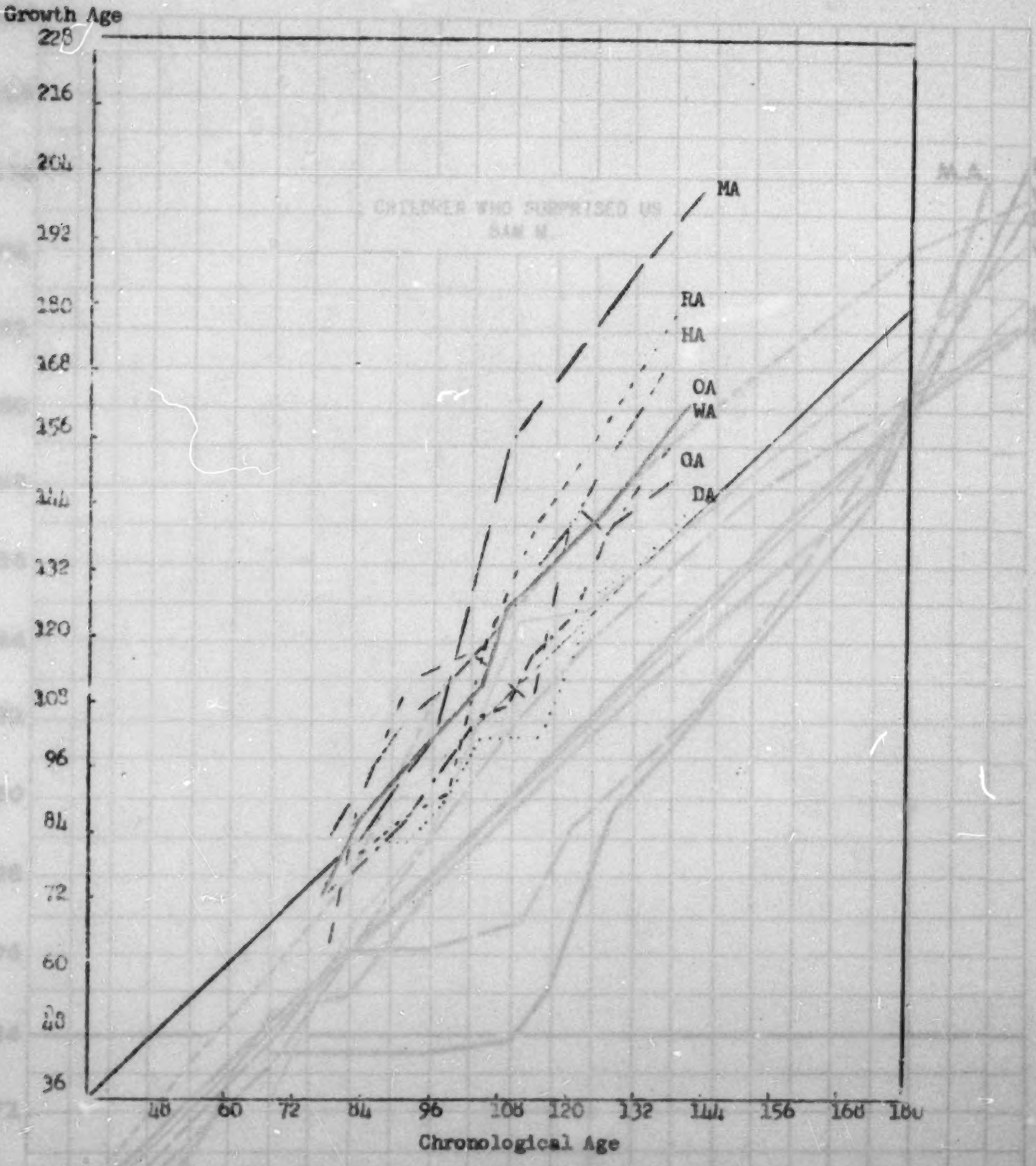

Figure 4. Longitudinal Growth Record of a Girl Showing Late and Rapid Linear Growth for Height Age (HA), Weight Age (WA), Grip Age (GA), Reading Age (RA), Mental Age (MA), and Organismic Age (OA) and Late and Slow Non-Linear Growth for Dental Age (DA).

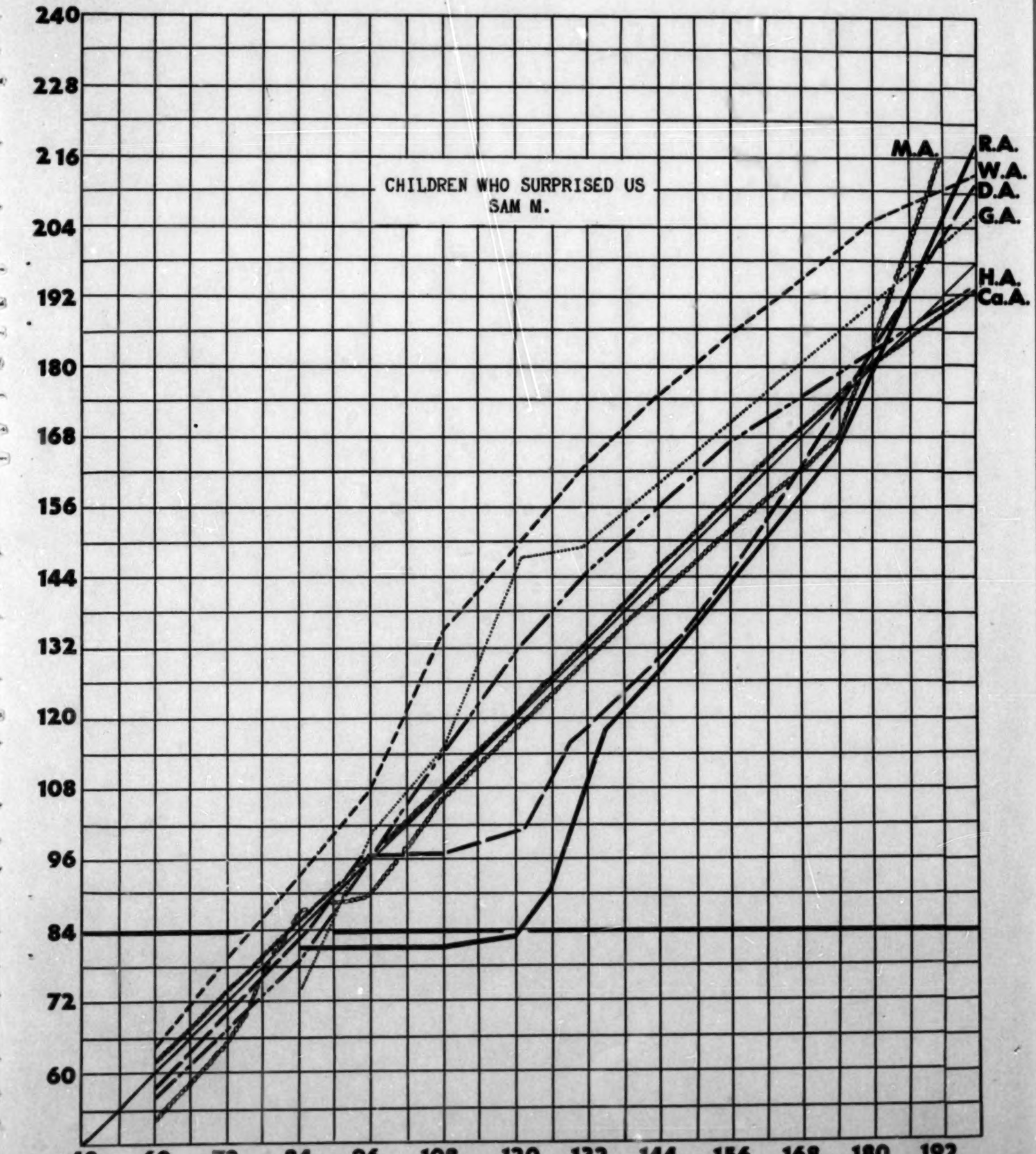

Figure 5.

Published by
Child Development Laboratories
University of Michigan
University Elementary School
Ann Arbor, Michigan
1950

Sibling Resemblances in Growth

Organismic theory emphasizes the importance of genetic factors in the individual's development. Evidence to support this emphasis has come from studies which compared similarities in growth between children of the same family with that of unrelated children. A number of studies reported in the literature deal with differences in growth between siblings (2,10,11). For the most part, these studies indicate a moderate positive relationship in the growth of sibling pairs. The present study has compared the differences in physical, mental, and academic development between siblings and non-siblings.

From the six hundred thirty-seven sets of siblings represented in the Ferndale data population, forty-four pairs were found whose growth records met the criteria for a longitudinal record. By extrapolation, the lines of best fit of the various growth age distributions were extended either upward or downward in order that the growth of all subjects might be compared at the common chronological age of one hundred months. The differences in growth age for each pair of siblings were added and divided by the number of sibling pairs. A mean difference between siblings was obtained for HA, WA, DA, GA, RA, MA, and OA.

The same records were used to secure a sample of unrelated children by matching the record of each child with the record of a child to whom he was not related. By adding the differences between pairs of children and dividing by the number of pairs, the mean differences between non-siblings were found for the different growth ages.

In Table 6 the mean differences between sibling pairs and non-sibling pairs for each growth age are compared. Significant differences were found between sibling pairs and non-sibling pairs for HA, WA, MA, and OA at chronological age one hundred months. The differences between siblings and non-

related children for DA, GA, and RA did not prove to be significant. When, however, the differences between sibling and non-sibling pairs for reading age were computed at chronological age one hundred forty-four months, significance was obtained.

Table 6

Mean Differences Between Sibling Pairs and Between Non-Related Pairs of Children at CA 100 months for Growth Ages and Significance of the Differences Between Mean Differences

	Sibling Pairs	Non-Related Pairs			
	Mean Difference	Mean Difference	Difference Between Mean Differences	t	P
HA	8.7411	16.4330	7.6919	3.7594	.0005
WA	14.2909	23.0332	8.7423	3.0577	.005
DA	9.1850	8.1440	1.0410	.4592	.7
GA	15.1954	16.1283	.9329	.3914	.7
*RA	16.3243	33.2568	16.9325	1.9107	.05
MA	9.1519	18.3597	9.2078	3.3055	.005
OA	6.2661	11.0757	4.8096	3.4601	.0005

*Obtained at 144 months CA

A possible explanation for this finding is that reading skills are neither fully established nor clearly differentiated for many children by chronological age one hundred months. Figure 3 reveals the range of individual differences in reading at one hundred months and at one hundred forty-four months of chronological age.

The Curvilinear Longitudinal Records

A number of longitudinal growth records were designated as non-linear by virtue of a coefficient of correlation of less than +.90 between the growth age distributions and chronological age. Many of these records contained distributions which appeared to be lawful and regular. On the basis of inspection, these distributions were classified as curvilinear. It must be emphasized that the terms "curve" and "curvilinear" as used in the present study involve empirical classification, not mathematical definition.

The curves that emerged may be thought of as belonging to two groups. Type I, a positively accelerated curve, is illustrated in Figure 5. The regularity and lawfulness of this subject's growth in weight is described by the equation $Y = be^{+aX}$ in which Y represents weight age, b represents rate, e represents the base of the system of natural logrithms, a represents the Y-intercept, and X represents chronological age. Negatively accelerated Type II curves are similar to the representation of a subject's mental growth in Figure 6. The equation of this parabola is $Y = a + bX + cX^{2}$* in which Y represents mental age, a represents the Y-intercept, b represents rate, X represents chronological age, and c represents a constant.

Table 7 reveals the number and percentage of occurrence of each type of curve for a representative sample of two hundred children. Seven growth age distributions for each child resulted in a total of fourteen hundred distributions. Forty-six (3.28 per cent) of these were curvilinearly distributed. Approximately two-thirds of the curves were Type I.

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* The two equations which were used to fit curves to the growth age distributions are found in

Peters, Charles C., and Van Voorhis, Walter R. Statistical Procedures and their Mathematical Bases. New York: McGraw-Hill, 1940. Chapter XV, pp. 425-444.

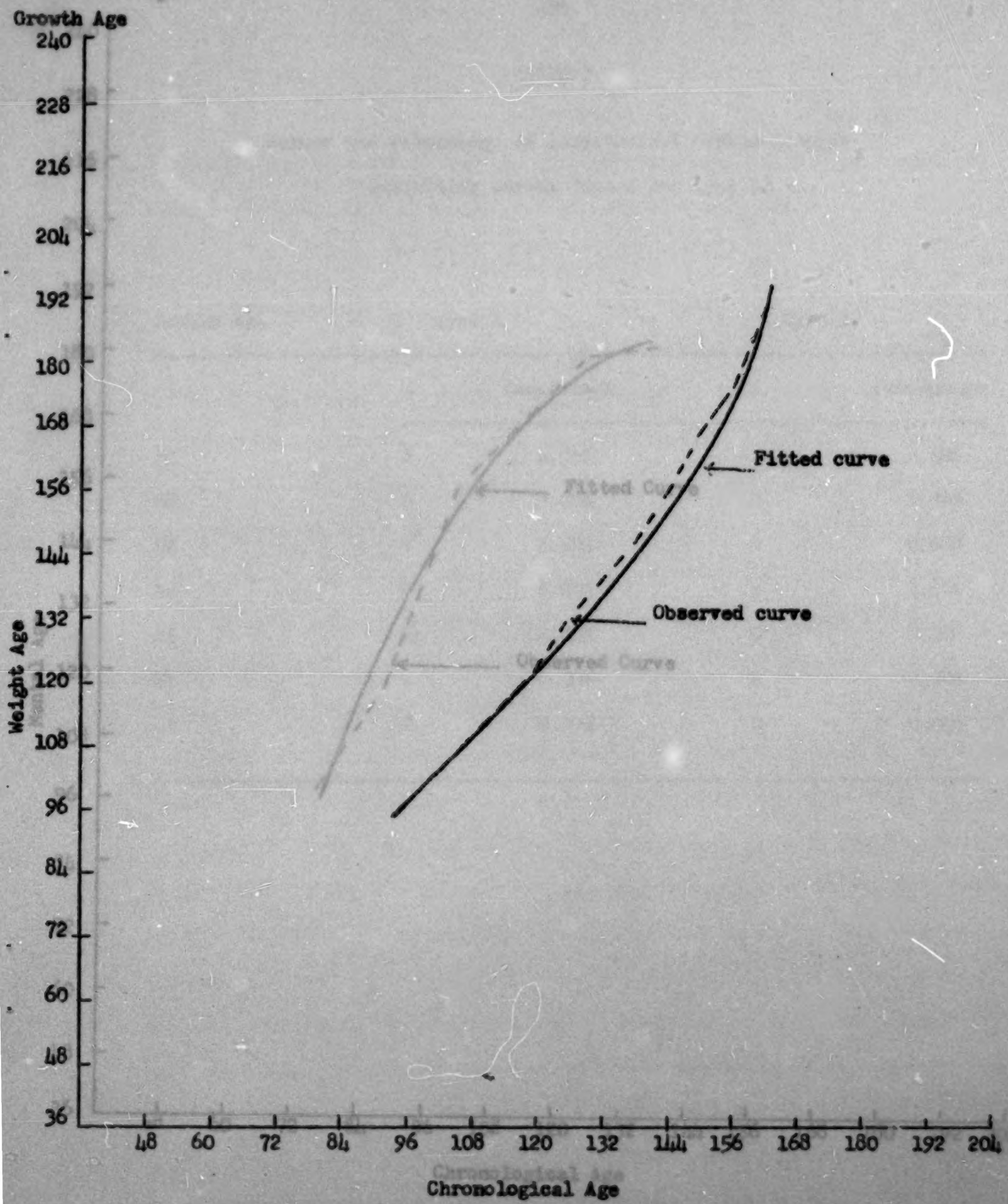

Fig. 6. Results of Application of the Formula $Y = be^{+aX}$ to the Curvilinear Weight Age Distribution of a Child Where X = CA, Y = WA, a = .0044 and b = 36.55.

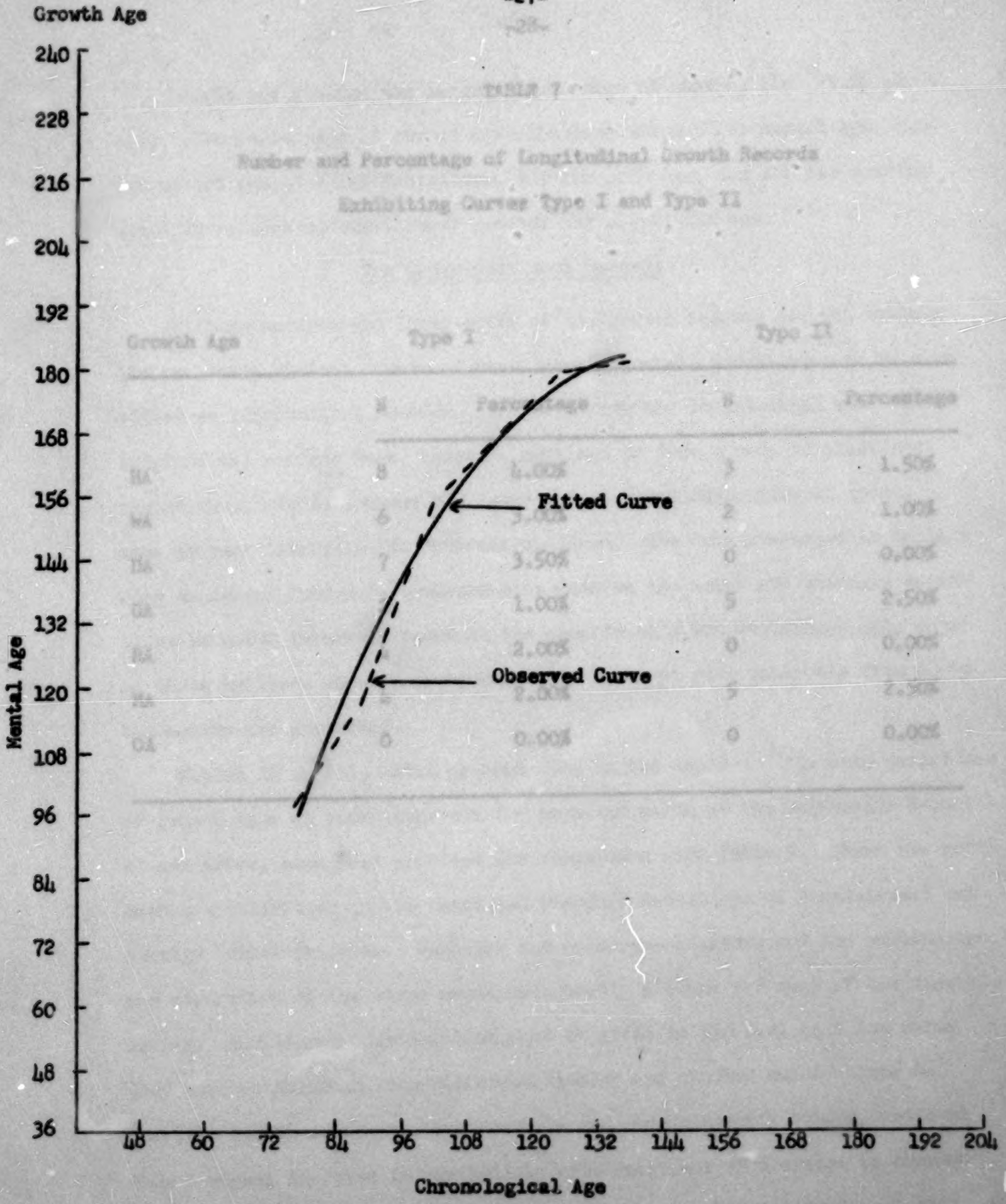

Fig. 7. Results of Application of the Formula $Y = a + bX + cX^2$ to the Curvilinear Mental Age Distribution of a Child Where X = CA, Y = MA, a = -253.5577, b = 6.2202, and c = .0221.

TABLE 7

Number and Percentage of Longitudinal Growth Records Exhibiting Curves Type I and Type II

Growth Age	Type I		Type II	
	N	Percentage	N	Percentage
HA	8	4.00%	3	1.50%
WA	6	3.00%	2	1.00%
DA	7	3.50%	0	0.00%
GA	2	1.00%	5	2.50%
RA	4	2.00%	0	0.00%
MA	4	2.00%	5	2.50%
OA	0	0.00%	0	0.00%

Height age yielded the largest percentage of curves; i.e., 5.50 per cent. The percentage of curved distributions was 4.5 for mental age, 4.0 for weight age, 3.5 for dental age, 3.5 for grip age, and 2.0 for reading age. There were no curvilinear records for organismic age.

The Cross-Sectional Records

Fifteen hundred and forty-seven of the growth records did not contain the necessary minimum number of measurements for all growth ages to be classified as longitudinal records. The data from the longitudinal and non-longitudinal records were, however, combined to form a body of cross-sectional data. Table 9 shows the means and standard deviations of growth ages at year intervals for Ferndale children. The data presented in Table 9 were condensed from more comprehensive data on the means and standard deviations at month intervals based on the records of 2,920 children. Only data on those children whose measurements were taken at year intervals from 60 to 144 months are presented.

Tables 10 and 11, which present data on the means and standard deviations of growth ages at year intervals for boys and girls at the University School at Ann Arbor, have been provided for comparison with Table 9. There are noticeable similarities in the means and standard deviations of Ferndale and University School children. Sampling and measurement errors and the combination and separation of the sexes would undoubtedly account for many of the discrepancies. Additional consideration must be given to the fact that the norms used were established from different samples and studies which relate to specific growth ages. At both Ferndale and the University School, children show a steady increase in variability with each year of increase in chronological age. Neither the Ferndale children nor the University School children show a mean reading age equal to their mean mental age. Among children at the

University School, the difference between the mean reading age and the mean mental age tends to decrease between chronological ages 84 and 144 months. The opposite trend is shown for Ferndale children. But the data on mental growth is derived from group tests at Ferndale and from the Stanford-Binet Tests of Intelligence at the University School. This circumstance could easily account for the differences in the comparison of mean reading and mean mental age between the two schools.

TABLE 8

Means and Standard Deviations

of Growth Ages at Year Intervals for Children in

the Ferndale School District

Height Ages				Weight Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60	51	66.4	8.6	60	51	73.2	12.2
72	141	77.6	8.3	72	141	82.0	13.6
84	168	89.6	11.9	84	168	94.6	17.8
96	213	101.9	13.3	96	212	107.2	19.4
108	219	116.6	14.0	108	219	121.6	20.4
120	161	129.8	14.6	120	160	135.1	20.6
132	111	143.2	16.6	132	111	149.0	22.0
144	57	153.3	18.4	144	58	158.3	22.1

Dental Ages				Grip Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60				60			
72	108	76.5	7.4	72	65	61.6	15.2
84	164	85.5	8.6	84	166	75.5	18.2
96	211	97.6	9.0	96	209	86.4	17.2
108	218	105.7	9.8	108	219	99.1	20.4
120	161	119.7	11.6	120	153	112.2	20.4
132	111	131.8	11.7	132	105	121.1	21.3
144	57	141.9	10.0	144	57	131.7	25.9

Reading Ages				Mental Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60				60			
72				72			
84	163	89.6	7.4	84	95	93.1	11.1
96	171	101.9	12.1	96	108	107.9	18.6
108	118	111.7	18.1	108	62	124.8	19.7
120	85	118.0	19.6	120	85	128.6	24.1
132	48	128.6	24.1	132	54	148.0	21.5
144	26	141.2	30.4	144	23	150.0	28.4

TABLE 9

Means and Standard Deviations

of Growth Ages at Year Intervals for Boys in the

University School

Height Ages				Weight Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60	73	65.23	6.5	60	74	68.05	10.6
72	80	76.21	8.1	72	82	80.49	14.4
84	73	88.36	11.1	84	75	92.64	14.6
96	71	104.31	11.5	96	70	106.97	17.3
108	63	119.24	12.5	108	63	123.57	19.2
120	56	132.52	12.7	120	57	136.37	19.9
132	47	143.96	11.7	132	47	145.81	20.4
144	20	151.85	11.7	144	19	153.89	21.9

Dental Ages				Grip Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60				60	66	64.55	13.9
72	45	76.76	6.6	72	75	82.44	13.4
84	62	86.85	8.8	84	75	95.52	15.0
96	65	97.25	9.3	96	69	108.33	15.1
108	64	105.80	8.2	108	62	123.16	18.5
120	56	115.48	12.0	120	55	135.27	16.2
132	47	128.96	13.4	132	46	146.20	17.7
144	22	142.64	13.8	144	17	151.12	22.1

Reading Ages				Mental Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60				60	65	72.95	7.1
72	47	79.91	7.2	72	85	84.33	10.3
84	87	85.69	9.4	84	83	97.08	10.9
96	80	95.83	15.6	96	76	112.87	13.8
108	75	111.88	22.8	108	73	129.38	19.3
120	67	130.90	28.0	120	64	142.66	22.2
132	55	149.82	29.9	132	51	157.18	22.7
144	24	154.83	24.5	144	22	157.59	28.7

TABLE 10

Means and Standard Deviations

of Growth Ages at Year Intervals for Girls in the

University School

Height Ages				Weight Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60	84	69.65	8.1	60	89	72.58	10.4
72	85	81.51	7.3	72	85	84.35	12.3
84	76	93.74	10.9	84	75	96.48	15.1
96	62	107.10	12.2	96	61	109.97	16.9
108	53	118.96	13.8	108	52	123.54	18.9
120	40	132.35	19.0	120	38	135.00	22.1
132	37	150.32	18.3	132	36	151.47	25.7
144	9	159.78	12.8	144	9	164.89	24.9

Dental Ages				Grip Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60				60	67	61.07	13.7
72	57	75.75	4.9	72	77	76.84	14.1
84	73	88.18	8.3	84	74	92.45	12.5
96	61	99.31	8.1	96	62	102.06	11.8
108	52	109.44	10.6	108	53	113.47	15.6
120	40	118.63	11.4	120	41	125.02	21.5
132	36	131.72	11.4	132	35	138.37	23.2
144	9	143.89	13.3	144	6	146.50	18.7

Reading Ages				Mental Ages			
Age Level	Number	Mean	Standard Deviation	Age Level	Number	Mean	Standard Deviation
60				60	71	74.63	6.2
72	38	79.63	6.4	72	86	85.74	7.4
84	81	87.62	9.2	84	82	99.13	8.2
96	73	99.60	12.8	96	70	112.54	10.0
108	64	113.67	16.9	108	62	128.84	13.2
120	58	134.64	23.7	120	53	144.36	18.8
132	48	152.77	28.0	132	43	158.02	22.2
144	12	156.83	33.0	144	14	161.14	28.2

SUMMARY AND RESULTS

The problem of this investigation was to organize and analyze longitudinal growth records of elementary school children which resulted from the testing program at Ferndale, Michigan. The purpose of the study was to determine whether the Ferndale data would support generalizations derived from studies of children in child study centers and laboratory schools. The study was needed since teachers frequently reject growth concepts as a basis for planning and improving school programs because they believe the concepts are biased by selected or privileged subjects.

The Results of the Investigation

The results of the investigation may be summarized as follows (see hypotheses on page 7):

1. The coefficients of correlation between the rates of growth of Ferndale children were not high. Nevertheless, the data provide strong support for a dynamic interrelationship of the variables studied. Twelve out of twenty-one coefficients of correlation were significantly greater than zero. With the exception of dental age, the coefficients of correlation between rate for organismic age and rate for the other growth ages were significant at the .01 level. Forty-five per cent of the children with linear records showed a common growth pattern for reading age and organismic age.
2. The elementary school children studied at Ferndale exhibited a systematic and continuous increase in physical, mental, and academic variability with increase in chronological age up to twelve years. Sufficient data to support this finding were available for height and weight beginning at age five, for dentition and grip strength beginning at age six, and for intelligence and reading skill beginning at age seven. The smallest increase in variability was shown for

dentition, while the largest increase in variability was shown for reading skill. Mental growth showed the second highest increase in variability. For a representative sample of 200 longitudinal records, the range in reading age increased from 32 months at age seven to 107 months at age twelve. The range in mental age increased from 65 months at age seven to 107 months at age twelve. According to the cross-sectional data, the standard deviation for reading age increased from 7.4 months at age seven to 30.4 months at age twelve and the standard deviation for mental age increased from 11.1 months to 28.4 months for the same period.

3. For the purpose of the present study, growth pattern was defined as a unique relationship between a child's longitudinal growth age distribution and calendar time as indicated by increases in chronological age. By using the y-intercept and slope of the regression line for linear growth age distributions, four distinct growth patterns were identified: (a) early and rapid, (b) early and slow, (c) late and rapid, and (d) late and slow. Earliness may also be interpreted to mean high initial status and lateness to mean low initial status. The largest percentages of Ferndale children proved to be late and rapid for all the growth variables excepting dental age. There was a larger percentage of children with linear records which showed late and rapid patterns than there were children with linear records which showed early and slow patterns. For height age, weight age, reading age, mental age, and organismic age, the smallest number of children showed late and slow patterns. The small number of late and slow records is undoubtedly attributable to the exclusion of children from special education classes.

4. The mean differences between groups of unrelated children were greater

than the mean differences between groups of siblings at 100 months of chronological age for height age, weight age, mental age, and organismic age. The differences were significant at the .01 level. The mean differences between the unrelated and sibling groups was not significant for reading age at age ten, but a P of .05 was obtained at age twelve. One possible interpretation of the data related to reading age is that instructional practices can alter genetically determined differences in reading achievement until about age ten, but after that age the children's basic nature will reassert itself in spite of early instructional practices which emphasize uniformity of the age of beginning reading. This interpretation of the data is supported to some extent by a comparison of the standard deviation of reading ages in Ferndale and the University School where instruction in reading is planned to fit individual differences to a greater extent than is usually thought to be possible. The standard deviation for reading age at the University School at age 84 months was 9.4 months for boys and 9.2 months for girls compared with a standard deviation of 7.4 months for Ferndale children of both sexes. However, by age twelve the standard deviation for reading age has become 24.5 months for boys and 33 months for girls at the University School and 30.4 months for Ferndale children. The standard deviations in mental age for the two schools are, however, very similar at ages seven and twelve.

5. It is indicated that the prediction of ultimate achievement from early growth status was difficult for most Ferndale children. Approximately 70 per cent of the children with linear records showed a tendency to reverse their growth status from high to low or conversely during the elementary school years. For reading age 9.9 per cent of the children

showed early superiority and rapid progress, whereby high status was maintained; 41.4 per cent showed early superiority and slow progress, which resulted in lowered status; 49.6 per cent showed early inferiority and rapid progress which resulted in raised status; and 1.7 per cent showed early inferiority and slow progress, whereby low status was maintained. The records for other growth ages showed very similar trends.

6. Without exception, the Ferndale children exhibited physical, mental, and academic growth through time. The children's growth was expressed through great diversity which has been described in terms of rate, level, and pattern. Interrelationships between the growth factors studied and the relationship of most growth factors to organismic age provide strong support for the assumption that there were basic differences in children's developmental potential.

Discussion of the Results

A description and analysis of data from the Ferndale testing program provides evidence regarding the results of growth among elementary school children in a typical school system. Since all of the children were cared for at home and taught at school, it is assumed that some of the results of their growth are attributable to the efforts of their parents and teachers. The present study does not present data regarding differences in the care, management, or teaching of the children. The study was designed, however, to show the relationship between inherent characteristics of the children and their growth. The specific parts of the study related to this purpose are: (a) the analysis of relationships between physical, mental, and reading growth; (b) the comparison of differences between siblings and unrelated children; and (c) a comparison of the Ferndale data and data collected at the University School in Ann Arbor. Findings from these parts of the study showed that, in

any evaluation of the results of physical, mental, and academic growth of children, their innate characteristics must be given due and careful consideration. An important corollary to this finding is the proposition that in an environment which provides adequate care, management, and instruction, the results of growth among children are lawful and are, consequently, not easily modified.

Given children of variable innate characteristics and adequate care, management, and instruction, the results of growth for groups of elementary school children can now be predicted with considerable accuracy. The most important, problematical, and certain result of growth is variability. The results of growth at a given chronological age or grade level can be described in terms of growth level with a group average or a national norm as the point of reference. At both Ferndale and the University School in Ann Arbor, the range of levels among children was already large upon their entrance to school, and the range increased with advancements in chronological age. The range in levels for the two school systems and the standard deviations were very similar in spite of differences in averages.

A very important, possibly the most important, innate characteristic of children is their growth rate. Growth rate was defined as the number of months of calendar time it takes a child to grow a given number of months of growth age. Ferndale children showed large individual differences in the chronological age at which they achieved seven years of reading age, which is the reading age of an average second grader. For a selected sample from eleven elementary schools, the range in chronological age at which seven years of reading age was achieved was from six years to nine and one-half years.

A unique value of the Ferndale data is derived from the access it provides to longitudinal records. The longitudinal type record provides a ready method for ascertaining the rate or direction of growth at a given status point for an

individual. As a result of unusually rapid or slow growth rates, children may exhibit idiosyncratic growth patterns which may make for dramatic changes in their growth status. Approximately three-fourths of the Ferndale children showed a change in growth status as a result of differential rates. This finding indicates that the simple and neat categorization of young children into instructional groups is not as easily accomplished as is sometimes indicated by those who indulge in the practice on the basis of growth status alone.

The foregoing discussion and interpretation of the findings of the Ferndale project suggest that the most important responsibility of parents and teachers is that of learning how to better cope with the large and dynamic variability in growth status, growth rate, and growth pattern which is to be expected among all growing children. The indication is that the results of a testing program similar to the ones at Ferndale and the University School would yield very similar data anywhere in the United States.

Conclusions

Conclusions of the Ferndale study may be summarized as follows:

1. When longitudinal growth records on children in a typical school system are analyzed, the results tend to support growth principles, concepts, and generalizations which have been derived from analyses of children's records in laboratory schools and child study centers.
2. Instruction in reading may get some children off to what appears to be an early start, but by the time children have completed the elementary grades developmental potential will reappear as the most important factor in determination of ultimate variance in reading skill.
3. The teachers of older and more advanced elementary school children should expect to face the task of coping with greater individual differences than the teachers of younger and less advanced elementary

school children, irrespective of the program of instruction or the administrative plan of the school.

4. The growth of most children is orderly and predictable, but individual growth patterns serve to alter the status of many children within their age-grade groups.

5. Much of the confusion over the purposes and results of education can be traced to the complexity of growth and the persistence with which growth asserts itself as a primary determinant of children's achievements.

POSSIBILITIES FOR FURTHER USE OF THE DATA

The usefulness of the Ferndale data has not been exhausted by the present study. In addition to their use in testing theoretical concepts of development, the Ferndale data are now available for future investigations of the interrelationship of child growth and school practices.

Developmental Differences Related to Sex

Research reveals great differences in growth between the two sexes. During part of childhood girls tend to be physically superior to boys. Preadolescent boys tend to reach sexual maturity and begin their growth spurt later than girls of the same age. Although these findings are widely accepted, there are unresolved questions for which these data might provide answers. Such questions might involve differences in growth patterns between the sexes and differences in the change of growth rates between the sexes.

Developmental Differences Related to Socioeconomic Status

Research indicates that development is indirectly related to socioeconomic status. Children of families in the upper and middle class groups tend to be healthier, taller, and heavier than children from lower class groups. How does membership in the lower class affect school achievement? Are differences in achievement between the social classes directly related to biological and health variables, or are there also contributing factors inherent in the home and family life of these children?

Developmental Differences Related to Classroom Practices

Unequivocal answers to many questions concerning the effects of various classroom practices are not available. The Ferndale data might be profitably employed to investigate such relationships as that between achievement and size of class and the relation of self-contained classrooms and the platoon program to achievement. Another informative study might involve the effects of absence or presence of report cards upon achievement.

Developmental Differences Related to Race

One of the ten elementary schools in Ferndale contains negro pupils exclusively. The data would provide interesting and important additions to existing information concerning the growth and development of these children. A hypothesis might involve the questions of whether real differences exist between this group and the entire pupil population in Ferndale.

Developmental Differences Between Exceptional Children

The Ferndale school system has a well organized system of special classes for pupils with various physical and mental handicaps. Important contrasts may exist between types of exceptional children. Does the presence of the exceptional child in a regular classroom have any appreciable effect upon his achievement? What effect would placement in a special class have on his achievement?

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